Limb sounding of the lunar limb with a Fourier transform spectrometer

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Planetary FTS at NASA GSFC

LSA 2
Lunar Superconductor Applications

- NASA Goddard has launched a series of Fourier transform spectrometers (FTS) to the solar system – including the IRIS on two Voyagers, and Cassini CIRS at Saturn

- Passive IR remote sensing in emission (limb & nadir) is a power tool for characterization of
  - Surface and atmosphere temperatures
  - Composition
  - Dynamics via the thermal wind equation

- Increased in size, culminating in 43 kg for CIRS, so develop CIRS-*lite* at 15-20 kg for future planetary missions

Developing CIRS-*lite*

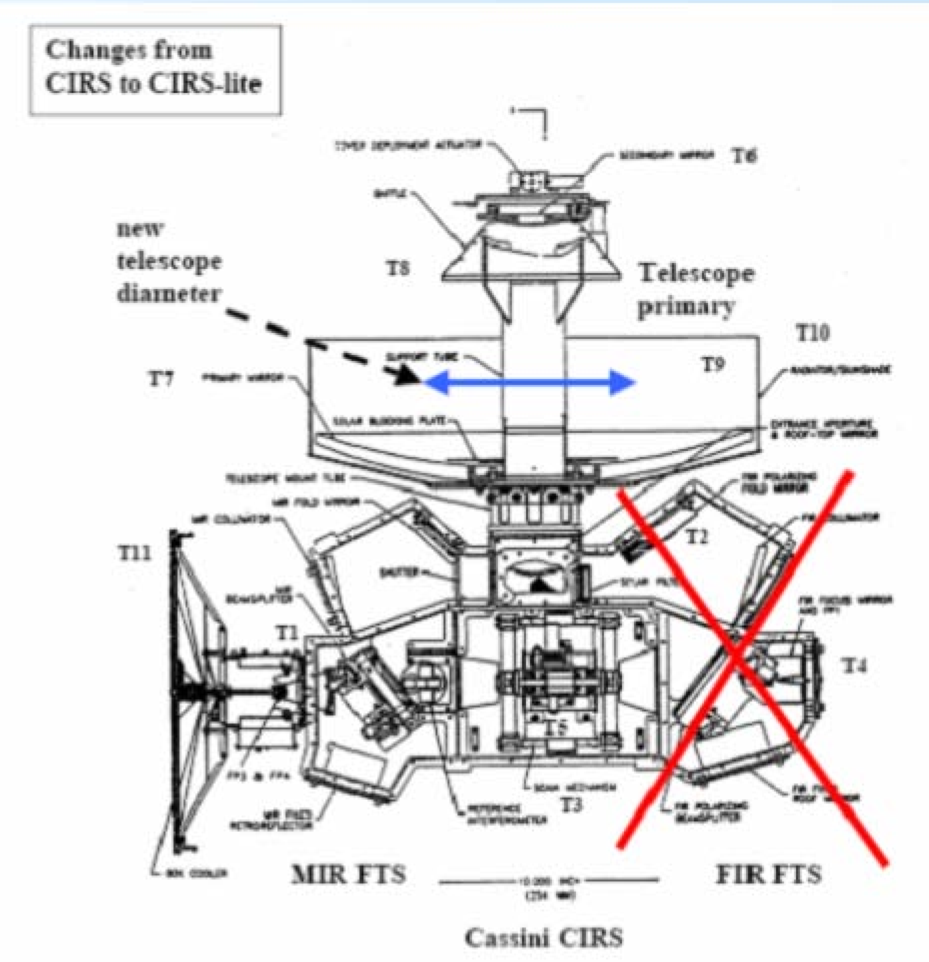
- Technology advances include:
  - high Tc superconductor bolometers (YBCO @ 87K, MgB_2 @ 37K)
  - Carbon nano-tube (CNT) layer for IR absorption
  - a COTS-based moving mirror mechanism compatible with near 77K operation
  - Synthetic (CVD) diamond beam-splitter
  - Single crystal silicon (SCS) telescope primary

- Very broad spectral coverage, ~ 7 to 300 microns, monitors a rich set of molecular lines

CIRS-*lite* and other FTS instruments

Parameter	**CIRS**	**CIRS-*lite***	**IRIS Mars**	**TES**	**PFS**
band-pass (μm)	7 to 1000	7 to 333	5 to 50	6 to 50	0.9 to 45
resolution (cm^{-1}) apodized	0.5	0.125	2.4	5	1.5
telescope diameter (cm)	50	15	4	15	5 /4
detectors	HgCdTe thermopile	HgCdTe high Tc	thermistor bolometer	DTGS pyroelec.	PbSe, PbS $LiTaO_3$
detector temperature (K) **optics temperature (K)**	75 and 170 170	75 and 89 ~150	250 250	Uncooled uncooled	210 and 290 290
point-able mirror	no	TBD 1 kg	no	yes	yes
footprint (km @ 250 km)	1 & 0.05	1 & 0.4	16	2	7 & 14
mass (kg)	43	15 to 20	14	14	31

CIRS to CIRS-*lite*

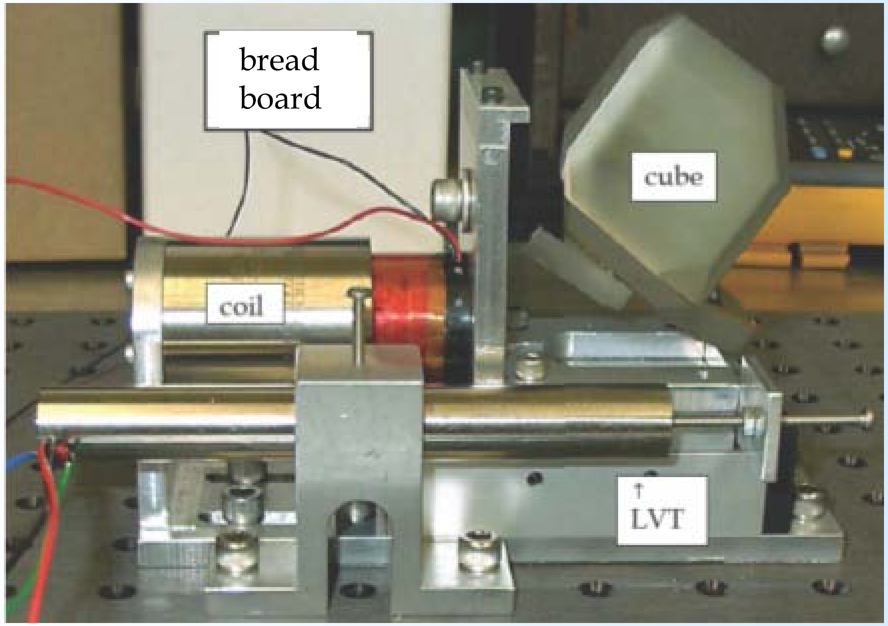


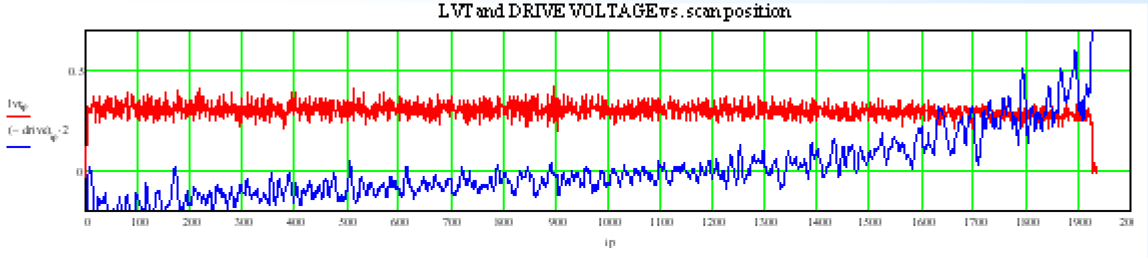
-CVD diamond has very broad transmission --> drop one FTS

- more sensitive FIR detectors (HTS bolometers vs. thermopiles) for smaller optics

- double-passed moving cube-corner enables higher spectral resolution

Moving mirror mechanism





Red: speed
Blue: drive force

CIRS-*lite* optical layout

Nominal design

Fig. 7

SCS

telescope primary

Lunar dust, volatiles

Mission	Science Goal	Optics temperature	Beam-splitter	detectors
Planetary deep space	atmospheres: composition, dynamics (remote sensing in emission)	~150K	diamond	HgCdTe high Tc bolometers
Lunar dust	Dust, gas (remote sensing via solar absorption)	~150K	KBr or diamond	HgCdTe thermal
Lunar surface ices	Near surface ice (in-situ) Reflection (NIR) Emission (FIR)	100K/ambient 100K/ambient	ZnSe (NIR) diamond (FIR)	HgCdTe (NIR) high Tc bolometer (FIR) MgB_2 (near 40K)

Solar occultation measurements: from surface, from orbit (limb view)

-lunar surface covered with dust grains levitated by charging mechanisms
- charging via solar wind and UV photons
- particular dust activity near the terminator (vacuum, little/no water)
- dust has implications for lunar exploration (adhesive, mechanisms, …)
- need to measure dust density, size distribution,
-measure vertical distribution from orbit via onion-peeling technique
- also measure H_20 and CH_4 from orbit

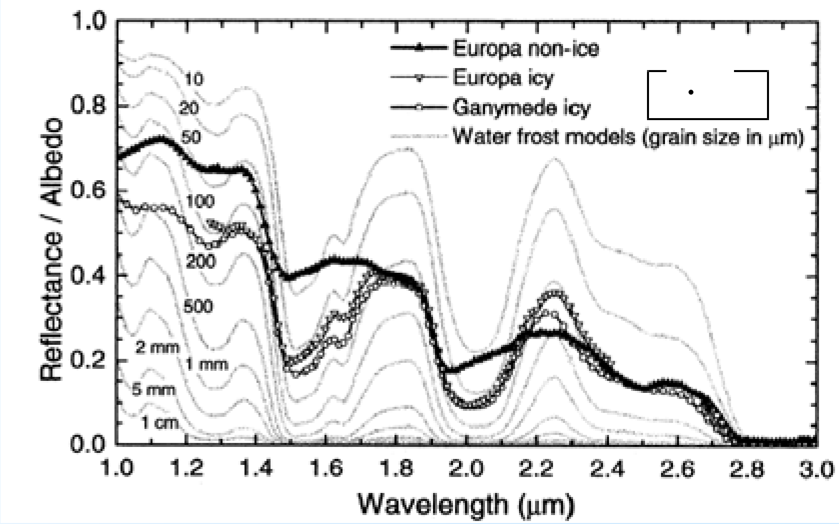
Lunar surface ices NIR

- Clementine radar, Lunar Prospector neutron spectrometer, and LRO/LEND indicate water ice or hydrogen deposits in permanently shadowed regions (PSR)
- LRO/LCROSS plume demonstrates hydroxyl group
- LRO/DIVINER temperatures consistent with ice
- Can distinguish hydrates from water ice via spectroscopy

- combine CIRS-lite with an NIR source (laser, LED or thermal) to measure NIR reflectance of surface deposits

- map concentration of water ice

- use laser source or ultrasonic generator to drive off volatiles and get indication of distribution with depth



Lunar surface ices FIR

LSA 2 Lunar Superconductor Applications

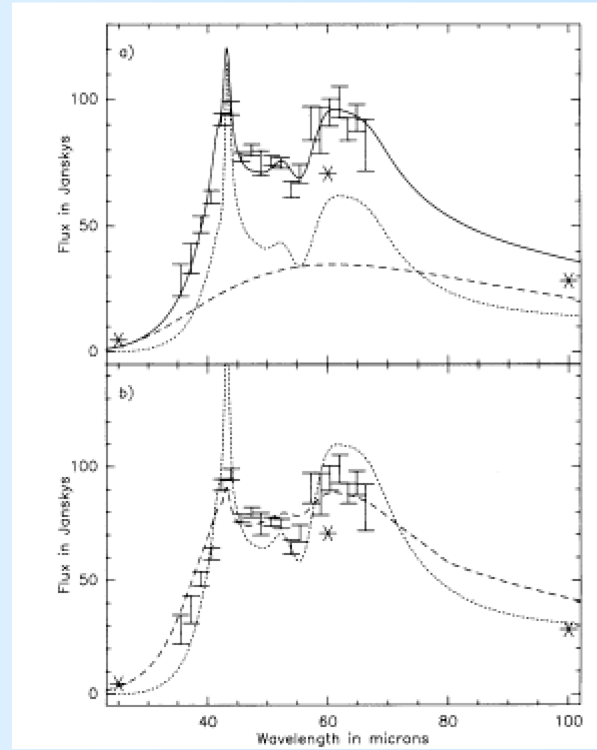
-FIR measurements (40 to 100 microns) can measure PSR temperatures (< 100K) and characterize two water ice features in the FIR

- in amorphous ice, longer peak is suppressed

- detection of these FIR emission features in an optically thick source such as the lunar surface requires a vertical temperature gradient

- thermal conductivity of slowly deposited amorphous ice is 10^4 times less than crystalline

- recent NASA GSFC results show MgB2 bolometers (37K transition) are much faster than YBCO bolometers (consistent with PSR operation)



Water ice FIR emission features observed in interstellar dust, with 40 and 60 micron peaks

THAT's All, FOLKS!